Report 14354-M-9

HYDROGEN-OXYGEN HIGH P_c APS ENGINES

NAS 3-14354

Period Ending 30 July 1971

L. Schoenman

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Engine Components Department
Aerojet Liquid Rocket Company
Sacramento, California

Prepared for
NASA-Lewis Research Center
Cleveland, Ohio 44135

AEROJET LIQUID ROCKET COMPANY
SACRAMENTO, CALIFORNIA • A DIVISION OF AEROJET-GENERAL

FOREWORD

The purpose of this contract is the development of a comprehensive technology base for high performance, long life, gaseous hydrogen-gaseous oxygen rocket engines suitable for the Space Shuttle APS. Significant goals in thruster design are a 50-hour firing life over a 10-year period, with up to 10^6 restarts, and single firings up to 1000 sec.

The program was initially structured as two parallel efforts: one directed toward high pressure (100 to 500 psia) systems and the other toward low pressure (10 to 20 psia) systems. Nominal engine thrust in each case is 1500 lb. Initial program tasks were devoted to the analytical evaluation and screening of injector and cooled thrust chamber concepts for both pressure levels. This was followed by closely paralleled but separate experimental evaluations of low and high pressure injectors and ignition devices. Recommendations of specific injector and igniter designs have been made for both pressure levels as a result of these tests.

As these parallel efforts were about to enter the cooled chamber fabrication phase, the program was redirected to apply additional emphasis on the high P_c technology with a revised schedule on propellant inlet temperatures. Activities on the low pressure phase were terminated by a stop work order, which eliminated the requirements for a portion of the injector testing and all of the low P_c cooled chamber fabrication, durability and pulse testing. The program's resources originally planned for these activities have been reallocated to expand design and test efforts related to the lower temperature gaseous propellants. The high P_c technology effort is now in, the full 40:1 nozzle/thrust chamber, assembly, test phase.

Mr. L. Schoenman, project manager for the high pressure phase, reports to Dr. R. J. LaBotz, who is program manager of all ALRC APS thruster programs. The NASA Lewis Research Center program manager is Mr. J Gregory.

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I. PROGRAM OBJECTIVES

The primary objective of this contract is to generate a comprehensive technology base for high performance gaseous hydrogen-gaseous oxygen rocket engines suitable for the Space Shuttle Auxiliary Propulsion System (APS). Durability requirements include injector and thrust chamber designs capable of 50 hours of firing life over a 10-year period with up to 10^6 pulses and single firings up to 1000 sec. These technical objectives are being accomplished and reported upon in a 28-task program summarized below. The first 10 tasks relate to high pressure APS engines, parallel tasks XI through XX relate to low pressure APS engines, and task XXI is a common reporting task. The additional tasks are for the expanded High P_c Low Temperature Program.

Task Titles	High P_c Task		Low P_c Task
	Amb. Prop.	Low Temp Prop.	
Injector analysis and design	I*	XXII	XI*
Injector fabrication	II*	XXIII	XII*
Thrust chamber analysis and design	III*	XXIV	XIII*
Thrust chamber fabrication	IV*	XXV	XIV*
Ignition system analysis and design	V*	--	XV*
Ignition system fabrication and checkout	VI*	--	XVI*
Propellant valves preparation	VII*	--	XVII*
Injector tests	VIII*	XXVI	XVIII*
Thrust chamber cooling tests	IX	XXVII	XIX*
Pulsing tests	X	XXVIII	XX*

Common Task

Reporting requirements XXI

*Completed tasks for revised program.

II. PROGRESS BY TASK

A. AMBIENT PROPELLANT TASKS

1. Tasks I through VIII

All activities on these tasks were completed prior to this report period.

2. Task IX - Cooled Thrust Chamber Testing

At the close of the report period, the following test conditions had been successfully demonstrated on the film cooled chamber design.

P_c psia	100	300	500
Mixture Ratios	3 through 5		
Fuel Temperature	200 - 550°R		
Oxidizer Temperature	320 - 550°R		

A summary of test conditions, test measurements, and performance data are presented in Table I. A description of these tests were presented in earlier reports.

3. Task X - Pulse Testing

No activity.

II, Progress by Task (cont.)

B. LOW TEMPERATURE PROPELLANT TASKS

1. Task XXII - Injector Analysis and Design

Design of light-weight, low volume injector manifolds suitable for low temperature propellants were completed in earlier report periods. The "I" pattern premix triplet face plates for S/N-6 injector were optimized based on the single element cold flow mixing test results reported in Task I, and the results of hot fire tests reported in Task VIII. The cold flow test results provided the optimum propellant momentum ratios and optimum geometry of the non-circular fuel orifices. The hot fire test results provided empirical data relating fuel orifice configuration to injector face temperature. The oxidizer orifice was also redesigned to provide a long L/D configuration and to allow propellant injection velocity and pressure drop to be independently optimized. Figure 1 provides a comparison of the three premix triplet injector elements evaluated in this program.

As of the end of this report period, the only remaining design activity is the final selection of the face plate pattern for the S/N-7 "I" unit which will be used with the S/N-3 regeneratively cooled chamber.

2. Task XXIII - Injector Fabrication

S/N-6 "I" premix triplet injector fabrication, instrumentation, and cold flow testing was completed during this report period. Fabrication and assembly of the component went exceptionally well. This injector was successfully tested in Task XXVI. The manifolding for the second unit S/N-7 which is identical to S/N-6 was also assembled via conventional hydrogen furnace braze and electron beam welding techniques, following the successful fabrication and testing of the first unit. Fabrication and assembly of the second body proved to be as exceptionally simple and smooth as the first. The remaining activities on S/N-7 involve:

II,B,2, Task XXIII - Injector Fabrication (cont.)

(1) bonding the selected face plate pattern
(2) welding the oxidizer inlet line
(3) final machining of seal surfaces
(4) cold flow
(5) instrumentation (six face thermocouples)

3. Task XXIV - Cooled Chamber Analysis and Design

As of the close of the report period, checked and released drawings were available for the three chambers being designed under this task as follows:

(1) film cooled chamber for 250°R H_2
(2) regeneratively cooled chamber for 250°R H_2
(3) light-weight film/dump cooled chamber suitable for reentry heating temperatures to 2000°F

Additional activities completed under this task were: (1) evaluation of metallic and nonmetallic skirt materials and coatings suitable for service at temperatures from 2000 to 3000°F, and (2) method of mechanically attaching these to current chamber designs.

Remaining activities in this task consist of completion of the life cycle analysis of the regeneratively cooled chamber assuming the boundary layer laminarizes and the life analysis of the manifolding of the film cooled chamber.

II,B, Low Temperature Propellant Tasks (cont.)

4. Task XXV - Cooled Chamber Fabrication

a. Regeneratively Cooled Chamber

Fabrication was initiated on S/N-3 regeneratively cooled chamber which was described in the last quarterly report. As of the close of this report period, fabrication was about 50% complete on both the slotted copper body and outer stainless steel jacket. The constant width (.062-.063 in.) variable depth slots were being cut along the contour using a tracer template at an average speed of 7 minutes per slot. Cutting tool life has been excellent. Fabrication of the coolant channel structural closeouts by photoetching trusses in .0625 steel plate were proceeding satisfactorily.

This chamber is scheduled to be delivered for final instrumentation in the latter part of August.

b. Film Cooled Chamber

There were no additional fabrication activities on the film cooled chamber beyond those listed in Quarterly Report #4. Fabrication activities were suspended pending the outcome of a structural analysis of a nonrestraining fuel inlet manifold.

5. Task XXVI - Injector Checkout Tests (Test Series 1680-D04)

a. Test Summary

Testing on this series was initiated in J-3 Altitude Test Facility with the following hardware:

II,B,5,a, Test Summary (cont.)

S/N-6 "I" premix triplet injector

S/N-1 Film cooled chamber

25-lb thrust spark igniter

Spacer ring which adapts S/N-6 injector to S/N-1 film cooled chamber

Facility operation and valves are identical to those discussed in earlier reports.

Testing during this report period proceeded as follows:

Tests 001-006 included facility checkout tests and a series of short 1-sec firings to check out the new injector face temperatures.

Test 007 was a nominal 300 psia test at TCA MR of 4.0, and 25% fuel film cooling. Steady-state thermal conditions were achieved throughout the chamber in this test.

Tests 008 & 009 were to be MR and film cooling survey tests. These were both terminated early because of an inoperative fuel film cooling valve. (In the MR - film cooling survey tests, a separate flow circuit and valve is employed to vary film cooling flow.) Failure of the valve to function in the latter test resulted in a burnout of the steel wall immediately downstream of the film cooling injection ring and damage to the tip of the copper ring.

Test 012 damaged S/N-1 film cooled chamber was replaced with S/N-2 unit which differs from S/N-1 in that it contains a zirconium copper liner rather than OFHC, and the skirt was uninsulated. Test 012 was of 100-sec duration and provided the following nominal data points at 300 psia chamber pressure.

MR	% FFC
4	29, 24, 19, 17
5	29, 24

II,B,5,a, Test Summary (cont.)

Test 014 was conducted with the same hardware at a chamber pressure of 500 psia for approximately 12 seconds. Data points on this test include:

MR	% Cooling
4	25
5	25

Test 015 was a low temperature propellant test at 300 psia. This test was terminated by computer malfunction detection system at FS_1 + .150 sec because the desired chamber pressure was not achieved. Failure to achieve ignition and thus chamber pressure was a result of not having the igniter power supply turned on. The preprogrammed computer monitoring system functioned exactly as expected.

Test 017 was a cold propellant test of 20-sec duration at 300 psia. Testing was terminated early because the mixture ratios could not be controlled by the computer due to very low oxidizer temperature. Temperatures below 320°R produce two-phase flow in the critical flow venturies. Propellant temperatures experienced during this test were 170°R for the fuel and 280°R on the oxidizer.

Test 018 was a 100-sec repeat test at 300 psia with slightly warmer oxidizer. Data points obtained are as follows:

Data Period (sec)	MR	% FFC
5-12	3	18.9
16-24	3	13.9
25-27	3	19.4
30-33	3	24.7
35-45	4	24.6
47-58	4	19.9
60-70	4	17.7
72-74	4	20.3
76-79	4	24.7
81-91	5	22.7
94-101	5	18.7

Hardware inspection following this series of tests showed all components in good condition.

II,B,5, Task XXVI - Injector Checkout Tests (cont.)

b. Test Results

(1) Performance

Measured performance data and computed parameters are summarized in Table I. These results are presented graphically in Figures 2 and 3. Figure 2 provides a comparison of the specific impulse for 300 psia ambient propellant operation at mixture ratios of 3 to 5 with film cooling flows of 15 to 30%. The lower portion of this figure provides additional dimensionless parameters including: % c* uncorrected, % of theoretical specific impulse, and % core energy release efficiency. The method of computing these parameters was presented in earlier reports.

S/N-6 "I" performance was found to be in good agreement with S/N-5 "I" data. The slightly higher performance on S/N-6 is attributed to the more uniform manifolding flow distribution and optimized element geometry. The film cooled chamber will require approximately 20% fuel film cooling to provide a life cycle capability of 10^5 thermal cycles at the throat.

The delivered vacuum specific impulse for this injector with the film cooled chamber at nominal operating conditions is

433 sec cold propellants (200°R fuel)
444 sec ambient propellants (530°R fuel)

Figure 3 provides a comparison of how each of the tested injectors behave when operated at off-design conditions; namely, chamber pressures of 300 and 500 psia, mixture ratios of 3 to 5, and respective O/F propellant temperatures of 320/200°R to 560/560°R. The significant aspect of the new injector design is that the % combustion efficiency is not influenced by propellant temperatures.

II,B,5,b, Test Results (cont.)

(2) Face Temperatures

Figure 4 provides a comparison of measured S/N-6 injector face temperatures with those recorded on S/N-3, -4, and -5 units. S/N-6 injector contains six face thermocouples located at three radial and two circumferential positions, as shown in Figure 5. Face temperatures on the S/N-6 "I" triplet are for the most part comparable to the cooler running S/N-4 triplet temperatures. The table in Figure 5 provides a list of these temperatures at various test conditions.

(3) Chamber Wall Thermal Data

The peripheral temperature patterns produced by S/N-6 injector in the film cooled chamber were very uniform. These are shown in Figure 6. The one slightly hotter area on the left side of the chamber is due to a small dent in the film coolant injection ring which occurred in the final fabrication assembly.

Thrust chamber wall temperatures at all of the 11 axial stations monitored were slightly cooler than those experienced with Task I injectors at the same flow conditions.

III. WORK DURING NEXT REPORTING PERIOD

Tasks I through VII - These tasks are complete; no new activities are planned.

Task IX - It is planned to complete testing in this task during the month of August.

III, Work During Next Reporting Period (cont.)

Task X - Set up and initiate pulse testing per the NASA approved test plan.

Task XXII - The faceplate pattern will be selected for S/N-7 premix "I" triplet based on the results of S/N-6 injector checkouts and bulk temperature rise data recorded on the regeneratively cooled chamber.

Task XXIII - Fabrication, cold flow and instrumentation of S/N-7 injector is to be completed during the month of August.

Task XXIV - Activities in the chamber design task will focus on verification of chamber life predictions using test data obtained in Tasks IX and XXVI 40:1 thruster testing.

Task XXV - Chamber fabrication will consist of completing fabrication of S/N-3 regeneratively cooled chamber, including those thermocouples which are brazed on the chamber wall.

Per approval of the NASA program manager, fabrication of a new film cooled chamber design optimized for use with low temperature propellants will not be completed. Parts completed to date, namely the spun Haynes 188 throat, will instead be employed to repair S/N-1 film cooled chamber which was damaged in Task XXVI testing due to the failure of the film cooling valve to open. This action was recommended on the basis that the projected time required to fabricate the revised design was not compatible with the program schedule. A portion of the funding planned for this activity will be used to repair the S/N-1 chamber. The remainder will be employed to expand structural and thermal analytical efforts related to these chamber designs.

III, Work During Next Reporting Period (cont.)

Task XXVI - Checkout testing of new low temperature injectors with Task III film and regeneratively cooled chamber designs is to be completed during the next report period.

Tasks XXVII and XXVIII - Test plans for these activities will be prepared and submitted for NASA program manager approval.

IV. PROBLEM AREAS

There are no technical or financial problem areas in this program. An accumulation of small slippages throughout the program, however, has produced a marginal condition on program schedule. It will be possible to complete the planned technical program by 15 October only if additional delays can be avoided.

FORECAST AND CONSUMPTION OF GOVERNMENT-FURNISHED PROPELLANTS

Contract NAS 3-14354

Material	June/July Monthly Usage	Cumulative	Next Month's Requirements	Next 3-Month Requirements
LO_2 (ton)	36.6	60	40	140
LH_2 (lb)	0	7210	0	0
LN_2 (ton)	68.2	485	150	400
GHe 10^3 (SCF), Bulk	0	99,100	12.5	25
GHe 10^3 (SCF), Cylinders	0	0	19	7

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Lewis Research Center

CONTRACT PROGRESS SCHEDULE

REPORT FOR MONTH ENDING: 30 July 1971

FORM APPROVED. BUDGET BUREAU NO. 104-R0007

9. NASA Use Only
a. NASA CODE
b. PROJECT MGR.
c. EVALUATION DATE
d. EXCEPTION CATEGORY
e. f. g.

1. CONTRACT TITLE: Hydrogen-Oxygen APS Engines (High P_c)

2. CONTRACTOR (Name and address): Aerojet Liquid Rocket Co., P.O. Box 13222 Sacramento, California 95813

3. CONTRACT NO.: NAS 3-14354

4. APPROVED (Contractor's Project Manager): L Shoeman

PREPARATION DATE: 8-05-71

5. NASA APPROVED SCHEDULE DATE: 8-31-70

7. 1970 1971
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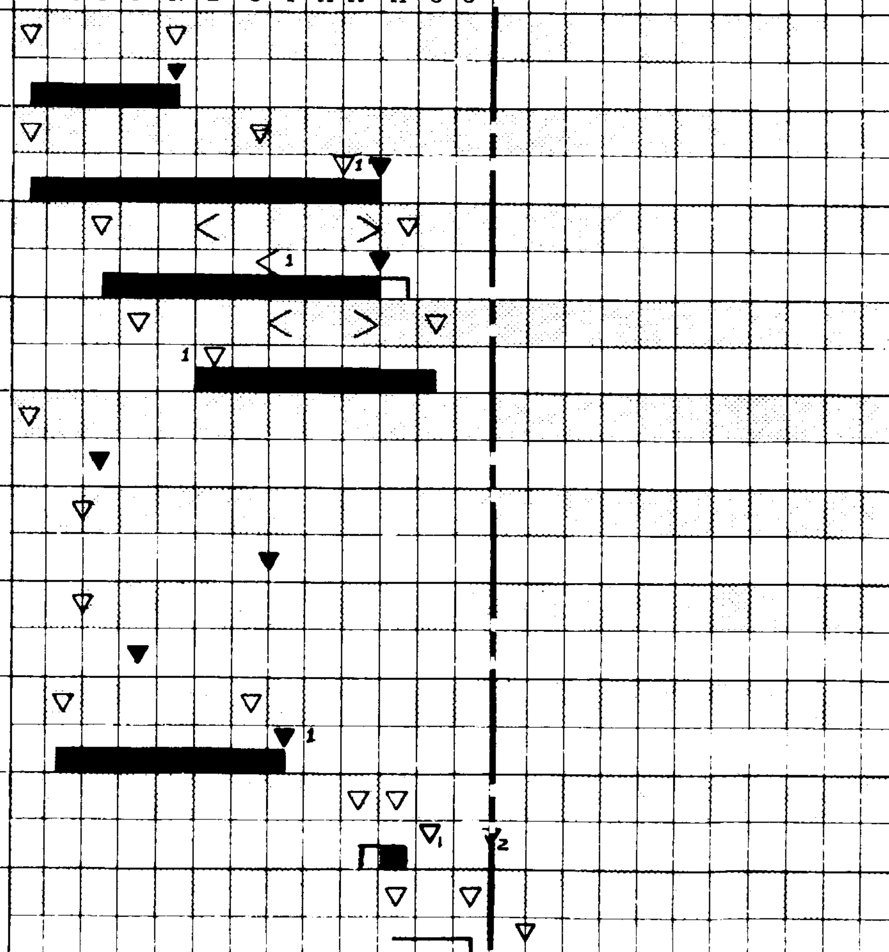

Task	6. REPORTING CATEGORY	8. TECH. OBJECTIVE % COMP.
I	Injector Analysis and Design	100
II	Injector Fabrication	100
III	Thrust Chamber Analysis and Design	100
IV	Thrust Chamber Fabrication	100
V	Ignition System Analysis and Design	100
VI	Ignition System Fabrication and Checkout	100
VII	Bipropellant Valve Preparation	100
VIII	Injector Tests	100
IX	Thrust Chamber Cooling Tests	55
X	Pulsing Tests	1

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NASA APPROVED SCHEDULE
CONTRACTOR'S WORKING SCHEDULE

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2. CONTRACTOR (Name and address): Aerojet Liquid Rocket Company, P.O. Box 13222 Sacramento, California

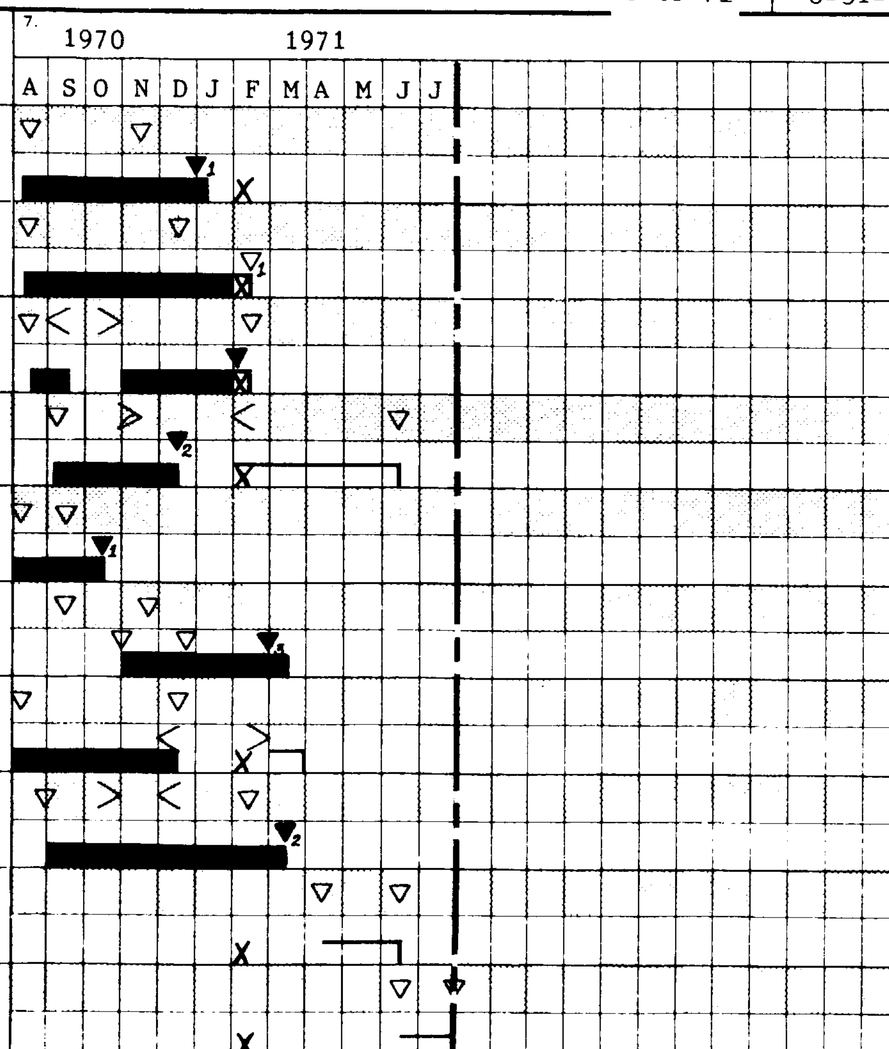
3. CONTRACT NO.: NAS 3-14354 Amendment I

4. APPROVED (Contractor's Project Manager): R A Dan

PREPARATION DATE: 8-05-71

5. NASA APPROVED SCHEDULE DATE: 8-31-70

Task	6. REPORTING CATEGORY	8. TECH. OBJECTIVE % COMP.
XI	Injector Analysis and Design	100
XII	Injector Fabrication	100
XIII	Thrust Chamber Analysis and Design	100
XIV	Thrust Chamber Fabrication	100
XV	Ignition System Analysis and Design	100
XVI	Ignition System Fabrication and Checkout	100
XVII	Bipropellant Valves Preparation	100
XVIII	Injector Tests	100
XIX	Thrust Chamber Cooling Tests	100
XX	Pulsing Tests	100



NASA C-63 (Rev. 1-68)

NASA APPROVED SCHEDULE
CONTRACTOR'S WORKING SCHEDULE

X Indicates activities halted by stop work order dated 11 February 1971.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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e. f. g.

Task	6. REPORTING CATEGORY	7. 1970: J A S O N D; 1971: J F M A M J J A S O N	8. TECH. OBJECTIVE % COMP.
XXI	Program Plan and Test Plans		
	High P_c		71
	Low P_c		100
	Monthly Reports		82
	Quarterly Reports		100
	Final Report Draft		25

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NASA APPROVED SCHEDULE
CONTRACTOR'S WORKING SCHEDULE

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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REPORT FOR MONTH ENDING: 30 July 1971

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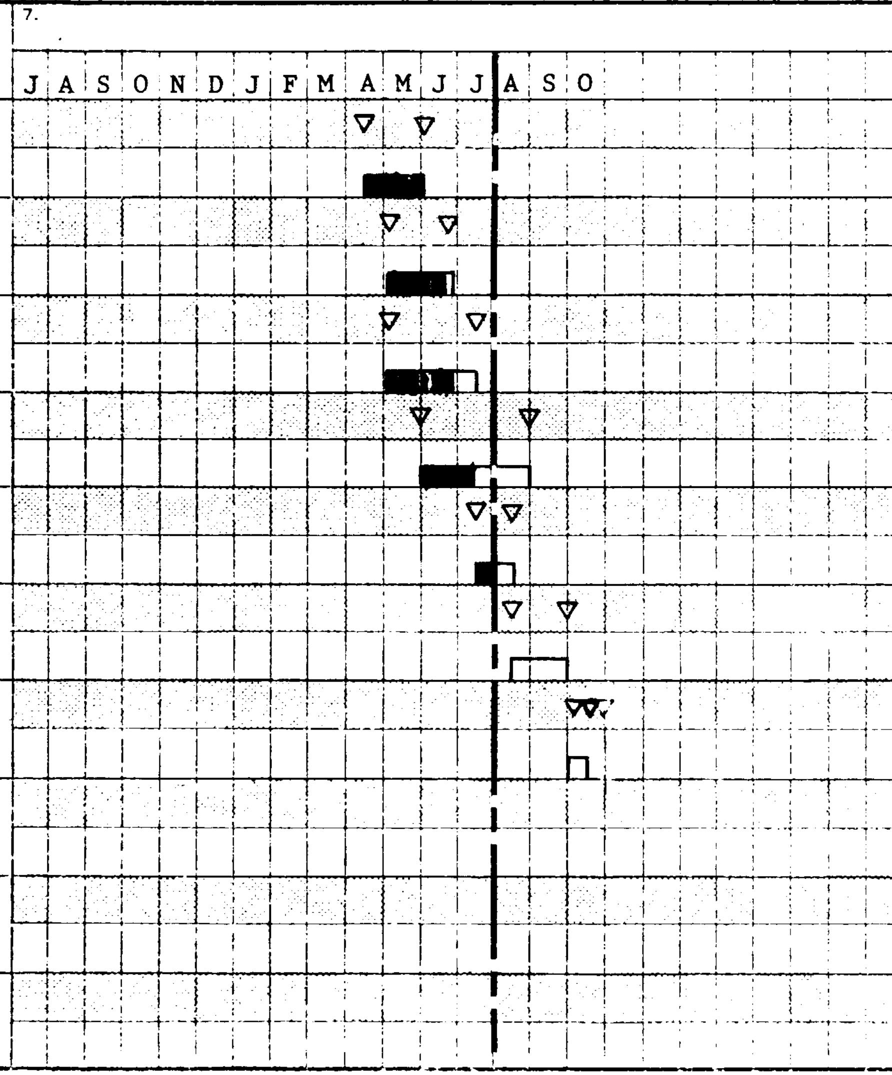


Task	6. REPORTING CATEGORY For Low Temperature Propellants	8. TECH OBJECTIVE % COMP.	e.	f.	g.
XXII	Injector Analysis & Design	95			
XXIII	Injector Fabrication	90			
XXIV	Thrust Chamber Analysis and Design	75			
XXV	Thrust Chamber Fabrication	25			
XXVI	Injector Checkout Tests	40			
XXVII	Cooled Chamber Tests	0			
XXVIII	Pulse Tests	0			

NASA C-(Rev. ...)

NASA APPROVED SCHEDULE

CONTRACTOR'S WORKING SCHEDULE

TABLE I

SUMMARY OF 40:1 TEST CONDITIONS AND HARDWARE

Test No.	Date	Injector SN	Chamber	Data Summary Period, sec	L'/L* in/in	P_c, psia	TCA MR O/F	% FFC	Prop. Temp. O_2/H_2 $^oR/^oR$
1680-D03-0A-001	System and Igniter Checkout Tests								
-002	System and Igniter Checkout Tests								
-003	System and Igniter Checkout Tests								
-004	System and Igniter Checkout Tests								
-005	4/30/71	2 I	3:1 FC	.4-.6	5.5/15	256	3.99	32.7	Amb.
-006	4/30/71	2 I	3:1 FC	.4-.96	5.5/15	269.4	3.000	32.05	
-007	4/30/71	2 I	3:1 FC	.4-.91	5.5/15	268.0	3.022	31.4	
-008	4/30/71	2 I	3:1 FC	15.0-20.0	5.5/15	250*	3.00	30.2	
-009	4/30/71	2 I	3:1 FC	5-10	5.5/15	258*	2.93	29.7	
-010	5/12/71				7.5/20	Sea Level - Igniter Only			
-011	5/12/71					Altitude - Igniter Only			
-012	5/12/71					P_{Alt} 1A Bad No Perf. Dam.			
-013	5/12/71	5 I	40:1 SN-1 FC	6.0-9.6		284.9	3.87	31.8	Amb.
-014	5/14/71	5 I		30-35		290.2	3.96	30.6	
-015	5/14/71	5 I		20-50		290.0	3.93	30.6	
				60-90		295.0	3.88	24.9	
				100-130		298.4	3.86	19.4	
				143-165		303.1	2.93	29.5	
				173-193		306.1	2.92	25.3	
				200-225		307.7	2.95	20.3	
				245-270		278.3	4.84	30.0	
-016	5/21/71	4 Trip		Computer Shut down due to amplifier malfunction					

* Data questionable. Instrumentation calibration shift during test

TABLE I (cont.)

Test No.	Date	Injector SN	Chamber	Data Summary Period, sec	L'/L* in/in	P_c', psia	TCA MR O/F	% FFC	Prop. Temp. O_2/H_2 $^oR/^oR$
1680-D03-0A-017	5/21/71	4 Trip	40:1 SN-1 FC	4.0-5.0	7.5/20	291.0	2.95	28.6	Amb.
				4.5-5.0		291.4	2.95	28.6	
-018				4.0-4.5		296.5	2.94	25.4	
				4.0-5.5		297.5	2.95	25.3	
-019				.5-1.5		276.0	4.00	23.7	
				3-8		284.4	3.98	25.1	
				9.2-11.5		289.2	3.94	19.1	
-020				.6-1.0		279.2	4.02	24.5	
				4.0-6.0		285.4	4.00	24.9	
				10.0-14.0		289.4	3.95	19.1	
				17.0-22.0		279.5	4.03	30.5	
				30-50.0		268.4	4.86	28.6	
-021				5-50		93.9	4.44	21.4	
				55-105		93.1	4.39	26.6	
-022	6/15/71			8-13		293.2	3.93	28.2	Cold
-023				9-14		287.4	4.05	28.0	
				19-23		256.4	5.18	29.5	
				30-34		284.3	4.05	24.1	
				36-50		282.7	4.13	20.0	
				54-58		285.7	4.08	23.9	
-024	6/18/71			5-16		479.5	3.95	29.0	Amb.
				19-23		486.1	3.92	24.3	
				26-34		480.3	3.95	29.0	

TABLE I (cont.)

Test No.	Date	Injector SN	Chamber	Data Summary Period, sec	L'/L* in/in	P_c, psia	TCA MR O/F	% FFC	Prop. Temp. O_2/H_2 $^oR/^oR$
1680-D04-0A-001-006	7/15/71	6 I	40:1 SN-1 FC	None	8.1/21.5	Checkout Tests			Amb.
-007						No valid performance data due to open check valve			
-008-009						No data - Film cooling valve failed to open			
-010-011			40:1 SN-2 FC			Computer shut down at .150 sec			
-012	7/16/71			5-25		298.9	3.8	18.9	Amb.
				30-45		302.5	3.8	18.9	
				49-59		302.6	3.8	16.9	
				63-65		292.2	3.9	29.8	
				68-73		281.7	4.8	29.0	
				78-94		284.7	49	24.1	
-013				No test					
-014	7/21/71			2-6		448.8	3.4	24.1	
				7-11		468.7	4.9	25.2	
-015				Igniter power not activated					
-016				Computer shut down due to low P_c in FFC manifold					
-017	8/3/71			0-20		Very low GO_2 temp - no flow data			280/170
-018				5-12		285.7	3.0	18.9	Cold
				16-24		285.8	3.0	13.9	
				25-27		281.0	3.1	19.4	
				30-32		276.1	3.1	24.7	
				35-45		276.7	4.1	24.6	
				47-58		266.3	4.2	19.9	
				60-70		267.5	4.2	17.7	
				72-74		266.2	4.2	20.3	
				76-79		268.9	4.0	24.7	
				81-91		262.3	4.9	22.7	
				94-101		268.0	4.8	18.7	

TABLE I (cont.)

Nomenclature List

PARAMATER	DEFINITION	UNITS
BLL	BOUNDARY LAYER LOSS	LBSF-SEC/LBSM
CSTAR	MEASURE CHARACTERISTIC EXHAUST VELOCITY	FT/SEC
C*	CHARACTERISTIC EXHAUST VELOCITY	FT/SEC
DATE	TEST DATE	----
DL	CURVATURE-DIVERGENCE LOSS	LBSF-SEC/LBSM
DP	DATA PERIOD	----
DT1	DATA TIME START	SEC.
DT2	DATA TIME END	SEC
ERE	ENERGY RELEASE EFFICIENCY	PERCENT
ERL	ENERGY RELEASE LOSS	LBSF-SEC/LBSM
FCL	FILM COOLING LOSS	LBSF-SEC/LBSM
FVAC	VACUUM THRUST	LBSF
IST	THEORETICAL VACUUM SPECIFIC IMPULSE	LBSF-SEC/LBSM
ISV	MEASURED VACUUM SPECIFIC IMPULSE	LBSF-SEC/LBSM
KL	KINETICS LOSS	LBSF-SEC/LBSM
MR	OVERALL MIXUTRE RATIO	----
MRC	CORE MIXTURE RATIO	----
MRD	IGNITER MIXTURE RATIO DISTRIBUTION LOSS	LBSF-SEC/LBSM
PA	ALTITUDE PRESSURE	PSIA
PC	CHAMBER PRESSURE	PSIA
TEST NUMBER	REFERENCE TEST SERIES AND NUMBER	----
TH2	HYDROGEN TEMPERATURE	DEG. RANKINE
TH2C	FILM COOLANT INLET TEMPERATURE	DEG RANKINE
TH2I	REGEN COOLANT INLET TEMPERATURE	DEG RANKINE
TH2OT	REGEN COOLANT OUTLET TEMPERATURE	DEG RANKINE
TO2	OXYGEN TEMPERATURE	DEG. RANKINE
WF	HYDROGEN MASS FLOWRATE	LBSM/SEC
WFC	FUEL COOLANT MASS FLOWRATE	LBSM/SEC
WFI	IGNITER HYDROGEN MASS FLOWRATE	LBSM/SEC
WO	OXYGEN MASS FLOWRATE	LBSM/SEC
WOI	IGNITER OXYGEN MASS FLOWRATE	LBSM/SEC
WT	TOTAL THRUSTER MASS FLOWRATE	LBSM/SEC
%C*	PERCENT CHARACTERISTIC EXHAUST VELOCITY	PERCENT
%FC	PERCENT OF TOTAL FUEL AS COOLANT	PERCENT
%IG	PERCENT OF TOTAL FLOW THROUGH IGNITER	PERCENT
%IS	PERCENT VACUUM SPECIFIC IMPULSE	PERCENT

TABLE I (cont.)

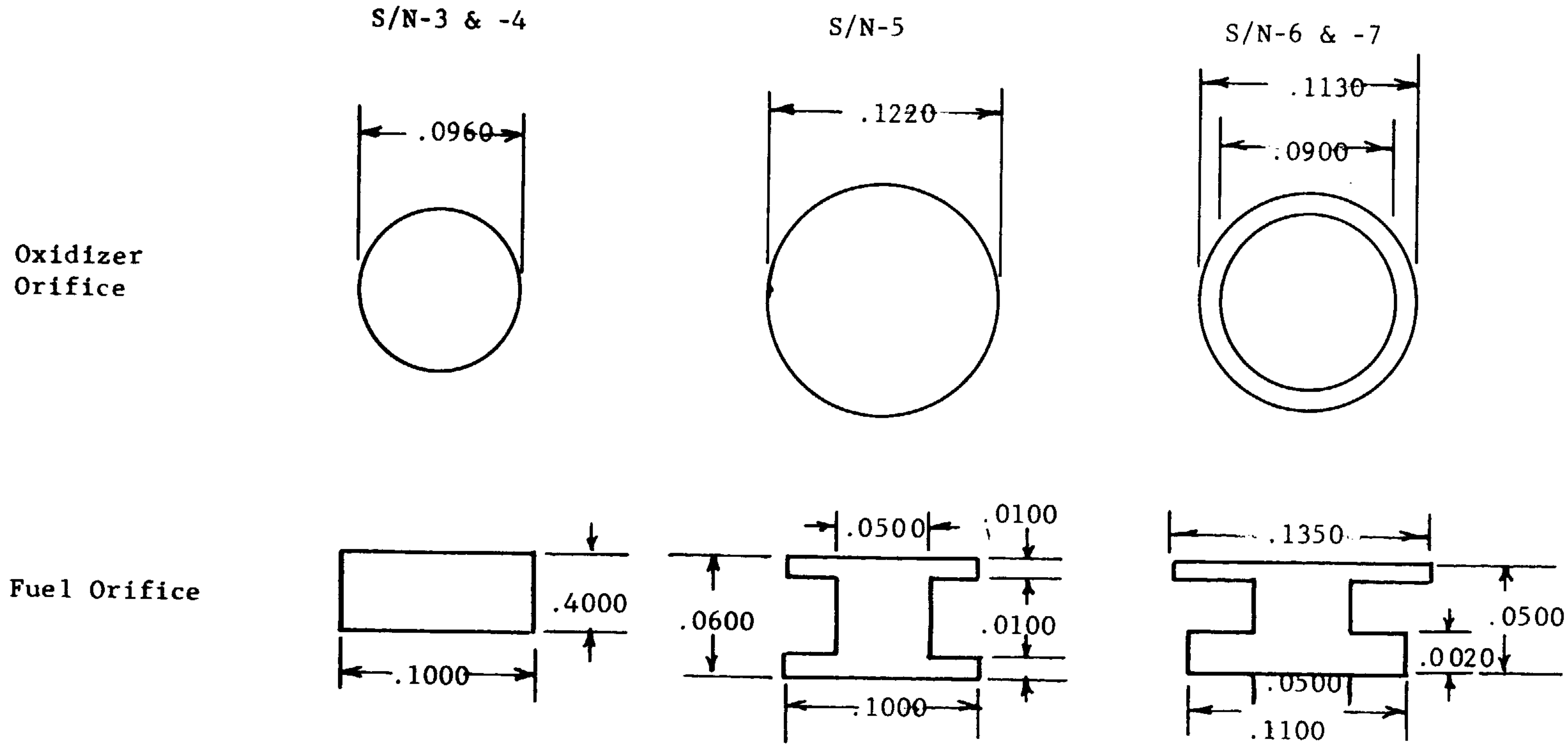
High Pressure APS Test Data Input

TEST NUMBER	MR	MRC	WO	WF	WFC	WFI	WT	TO2	TH2IN	TH2OT	TH2C	PC	PA	FVAC	CSTAR	ISP	%IG	%FC
1680-D03-0A-013	3.87	5.87	2.80	.48	.23	.02	3.52	533.6	544.9	717.0	629.7	284.9	1.0	1473.4	7438.3	429.2	.48	31.8
1680-D03-0A-014	3.96	5.90	2.81	.48	.22	.02	3.52	532.8	559.1	734.1	650.3	290.2	1.1	1415.6	7583.2	423.5	.46	30.6
1680-D03-0A-015	3.93	5.86	2.79	.48	.22	.02	3.50	533.4	552.0	726.2	641.0	289.0	1.1	1496.9	7583.8	431.6	.46	30.6
1608-D03-0A-015	3.88	5.32	2.79	.52	.18	.02	3.51	532.5	546.7	707.7	660.3	295.0	1.2	1522.0	7727.0	437.9	.46	24.9
1608-D03-0A-015	3.86	4.92	2.79	.57	.14	.02	3.51	531.8	541.7	691.9	689.3	298.4	1.2	1536.7	7803.9	441.5	.46	19.4
1680-D03-0A-015	2.93	4.26	2.62	.61	.26	.02	3.52	527.1	533.1	673.3	608.0	303.1	1.2	1526.8	7921.2	439.0	.47	29.5
1680-D03-0A-015	2.92	4.01	2.62	.65	.23	.02	3.52	527.8	529.4	662.5	620.0	306.2	1.2	1525.7	8004.3	444.0	.47	25.3
1680-D03-0A-015	2.95	3.79	2.62	.69	.18	.02	3.51	527.5	521.9	648.3	640.8	307.7	1.2	1522.0	8065.9	448.0	.47	20.3
1680-D03-0A-015	4.84	7.21	2.91	.40	.18	.02	3.51	528.4	525.2	724.4	631.2	278.3	1.2	1397.1	7277.8	414.0	.47	30.1
1608-D03-0A-017	2.95	4.24	2.51	.59	.24	.02	3.36	516.5	531.7	672.5	612.2	291.0	.6	1460.6	7948.1	434.1	.48	28.6
1680-D03-0A-017	2.95	4.24	2.52	.59	.24	.02	3.37	516.3	532.1	673.0	613.0	291.4	.7	1468.6	7950.7	436.0	.48	28.6
1680-D03-0A-018	2.94	4.04	2.54	.63	.22	.02	3.41	513.7	530.0	664.6	622.2	296.5	.7	1487.9	7995.2	436.6	.48	25.4
1680-D03-0A-018	2.95	4.05	2.55	.63	.22	.02	3.41	514.2	530.3	665.1	623.8	297.5	.9	1489.9	8007.6	436.5	.48	25.3
1680-D03-0A-019	4.00	5.43	2.66	.49	.16	.02	3.33	508.7	515.2	678.4	630.1	276.0	.2	1412.6	7626.8	424.8	.51	23.7
1680-D03-0A-019	3.98	5.49	2.74	.50	.17	.02	3.43	508.0	523.5	687.5	639.2	284.5	.3	1460.2	7622.5	425.8	.49	25.1
1680-D03-0A-019	3.94	5.02	2.74	.55	.13	.02	3.43	510.9	528.0	680.3	676.4	289.1	.6	1476.8	7745.8	430.5	.48	19.1
1680-D03-0A-020	4.02	5.52	2.70	.49	.16	.02	3.37	503.2	515.1	680.4	629.9	279.2	.2	1424.6	7623.7	423.3	.51	24.5
1680-D03-0A-020	4.00	5.51	2.75	.50	.17	.02	3.44	506.5	522.5	686.9	639.2	285.4	.3	1464.6	7618.3	425.4	.49	25.0
1680-D03-0A-020	3.95	5.03	2.75	.55	.13	.02	3.44	511.0	528.8	681.2	680.2	289.5	.7	1473.8	7732.8	428.4	.48	19.1
1680-D03-0A-020	4.03	6.01	2.74	.46	.21	.02	3.42	516.4	532.4	709.5	626.5	279.5	1.0	1415.2	7507.5	413.7	.48	30.5
1680-D03-0A-020	4.96	7.35	2.86	.39	.17	.02	3.43	516.9	531.7	732.8	641.2	268.4	.6	1409.7	7182.0	410.5	.48	29.6
1680-D03-0A-021	4.47	5.90	.94	.16	.05	.01	1.15	501.3	519.0	730.1	696.8	93.9	.1	480.4	7514.5	418.1	.52	21.4
1680-D03-0A-021	4.39	6.22	.94	.15	.06	.01	1.15	493.5	519.5	741.8	660.2	93.1	.1	474.4	7429.3	411.9	.52	26.6
1680-D03-0A-022	3.93	5.64	2.93	.52	.21	.02	3.67	340.9	199.6	361.3	306.1	293.1	1.5	1552.8	7338.1	423.0	.44	28.2
1680-D03-0A-023	4.05	5.80	2.95	.51	.20	.02	3.68	321.1	199.5	362.2	295.2	287.4	1.3	1507.9	7187.3	410.3	.44	28.0
1680-D03-0A-023	5.18	7.65	2.94	.38	.17	.02	3.51	319.4	201.9	398.2	333.7	256.5	1.2	1363.6	6719.8	388.8	.46	29.5
1680-D03-0A-023	4.05	5.50	2.93	.53	.17	.02	3.65	324.5	234.6	388.4	359.0	284.3	1.1	1517.7	7154.5	415.5	.44	24.1
1680-D03-0A-023	4.13	5.32	2.92	.55	.14	.02	3.63	331.5	232.0	380.4	382.8	282.7	1.5	1511.8	7158.7	416.6	.44	20.0
1680-D03-0A-023	4.08	5.52	2.92	.53	.17	.02	3.63	339.2	227.6	383.3	353.8	285.7	1.7	1501.8	7230.2	413.6	.44	23.9
1680-D03-0A-024	3.95	5.73	4.63	.81	.34	.02	5.80	530.8	541.7	695.7	631.7	479.5	.8	2505.8	7596.4	432.0	.42	29.0
1680-D03-0A-024	3.92	5.32	4.63	.87	.29	.02	5.81	528.9	543.0	687.7	650.4	486.1	.7	2543.2	7694.3	438.1	.42	24.3
1680-D03-0A-024	3.95	5.73	4.63	.81	.34	.02	5.80	528.0	541.7	695.9	633.4	480.3	.7	2523.0	7607.8	434.9	.42	29.0
1680-D04-0A-012	3.83	5.21	2.85	.55	.18	.02	3.59	530.5	549.8	705.8	662.9	298.9	1.0	1575.8	7681.1	438.8	.46	24.2
1680-D04-0A-012	3.82	4.84	2.85	.59	.14	.02	3.60	521.3	547.4	693.4	692.5	302.5	.8	1601.1	7748.7	444.5	.47	18.9
1680-D04-0A-012	3.83	4.73	2.86	.60	.13	.02	3.60	517.5	544.0	686.7	707.8	302.6	.7	1605.9	7752.5	445.9	.47	16.9
1680-D04-0A-012	3.90	5.75	2.86	.50	.22	.02	3.59	516.1	542.5	710.9	633.3	292.2	.7	1561.5	7513.1	435.1	.47	29.8
1680-D04-0A-012	4.81	7.05	2.99	.42	.18	.02	3.61	515.9	542.2	734.3	649.4	281.7	.7	1524.2	7209.9	422.7	.47	29.0
1680-D04-0A-012	4.87	6.65	2.98	.45	.15	.02	3.60	515.1	542.0	724.8	673.3	284.7	.6	1540.4	7306.4	428.4	.47	24.1
1680-D04-0A-014	3.42	4.63	4.03	.87	.28	.02	5.20	547.8	546.2	681.9	643.8	448.8	1.3	2340.9	7959.9	449.9	.47	24.1
1680-D04-0A-014	4.95	6.84	4.85	.71	.25	.02	5.83	546.1	544.8	717.1	664.4	468.7	1.2	2526.8	7423.0	433.6	.42	25.2
1680-D04-0A-018	3.03	3.82	2.50	.65	.16	.02	3.32	454.1	184.4	310.2	383.0	285.7	.9	1446.7	7931.3	435.3	.47	18.9
1680-D04-0A-018	2.95	3.51	2.48	.71	.12	.02	3.31	433.3	191.1	307.6	442.3	285.8	.8	1438.1	7957.8	434.0	.48	13.9
1680-D04-0A-018	3.05	3.89	2.46	.63	.16	.02	3.27	424.1	208.1	336.2	377.8	281.0	.8	1412.4	7935.9	432.4	.48	19.4
1680-D04-0A-018	3.13	4.27	2.45	.57	.19	.02	3.23	419.9	213.3	352.9	340.4	276.1	.8	1397.5	7889.1	432.9	.49	24.7
1680-D04-0A-018	4.12	5.65	2.61	.46	.16	.02	3.25	412.4	198.8	372.2	378.6	276.7	.7	1388.0	7608.9	427.6	.48	24.6
1680-D04-0A-018	4.23	5.45	2.59	.47	.12	.02	3.20	407.0	188.3	352.0	412.1	266.3	.7	1383.5	7674.0	432.1	.48	19.9
1680-D04-0A-018	4.22	5.28	2.58	.49	.11	.02	3.20	404.3	190.8	350.3	428.2	267.5	.7	1388.6	7720.3	434.4	.48	17.7
1680-D04-0A-018	4.21	5.45	2.58	.47	.12	.02	3.19	403.9	192.1	356.2	390.0	266.2	.7	1382.9	7687.8	432.8	.48	20.3
1680-D04-0A-018	4.04	5.53	2.58	.47	.16	.02	3.22	404.1	192.5	359.8	342.9	268.1	.7	1390.7	7672.2	431.3	.47	24.7
1680-D04-0A-018	4.89	6.56	2.71	.41	.13	.01	3.26	405.5	193.8	379.8	394.9	262.3	.7	1379.4	7418.9	422.8	.46	22.7
1680-D04-0A-018	4.77	6.06	2.71	.45	.11	.01	3.28	408.0	191.9	366.6	428.5	268.0	.6	1409.7	7541.3	429.9	.45	18.7

TABLE I (cont.)

High Pressure APS Test Summary and Performance Data

TEST NUMBER	DP	DATE	DT1	DT2	PC	TO2	TH2	MR	MRC	%FC	%C*	%IS	C*	IST	ISV	KL	MRD	BLL	DL	FCL	ERL	ERE
1680-D03-0A-013	1	05-12-71	6.0	9.6	284.9	533.6	544.9	3.9	5.9	31.8	90.3	90.7	7438.3	473.3	429.2	3.9	.6	8.2	3.4	14.8	13.1	97.2
1680-U03-0A-014	1	05-14-71	5.0	35.0	290.2	532.8	559.1	4.0	5.9	30.6	92.3	89.5	7583.2	473.3	423.5	4.1	.6	8.5	3.3	15.0	18.2	96.2
1680-D03-0A-015	1	05-14-71	20.0	50.0	289.0	533.4	552.0	3.9	5.9	30.6	92.2	91.2	7583.8	473.3	431.6	4.1	.6	8.5	3.4	14.7	10.4	97.8
1608-D03-0A-015	2	05-14-71	60.0	90.0	295.0	532.5	546.7	3.9	5.3	24.9	93.8	92.5	7727.0	473.3	437.9	3.9	.6	8.6	3.4	10.2	8.6	98.2
1608-D03-0A-015	3	05-14-71	100.0	130.0	298.4	531.8	541.7	3.9	4.9	19.4	94.7	93.3	7803.9	473.3	441.5	3.9	.6	8.6	3.5	6.8	8.4	98.2
1680-D03-0A-015	4	05-14-71	143.0	165.0	303.1	527.1	533.1	2.9	4.3	29.5	94.5	93.3	7921.2	470.4	439.0	1.7	.4	7.1	3.5	5.9	12.9	97.3
1680-D03-0A-015	5	05-14-71	173.0	193.0	306.2	527.8	529.4	2.9	4.0	25.3	95.5	94.4	8004.3	470.4	444.0	1.7	.4	7.1	3.5	5.1	8.5	98.2
1680-D03-0A-015	6	05-14-71	200.0	225.0	307.7	527.5	521.9	3.0	3.8	20.3	96.3	95.2	8065.9	470.5	448.0	1.8	.4	7.2	3.5	4.2	5.4	98.9
1680-D03-0A-015	7	05-14-71	245.0	270.0	278.3	528.4	525.2	4.8	7.2	30.1	91.1	87.9	7277.8	471.0	414.0	5.9	1.6	8.8	3.3	22.3	15.2	96.8
1608-D03-0A-017	1	05-21-71	4.0	5.0	291.0	516.5	531.7	2.9	4.2	28.6	94.9	92.3	7948.1	470.5	434.1	1.8	.4	7.2	3.4	5.8	17.9	96.2
1680-D03-0A-017	2	5-21-71	4.5	5.0	291.4	516.3	532.1	2.9	4.2	28.6	94.9	92.7	7950.7	470.5	436.0	1.8	.4	7.2	3.4	5.8	16.0	96.6
1680-D03-0A-018	1	05-21-71	4.0	4.5	296.5	513.7	530.0	2.9	4.0	25.4	95.4	92.8	7995.2	470.5	436.6	1.7	.4	7.2	3.4	5.2	16.0	96.6
1680-D03-0A-018	2	05-21-71	4.0	5.5	297.5	514.2	530.3	2.9	4.0	25.3	95.6	92.8	8007.6	470.5	436.5	1.8	.4	7.2	3.4	5.2	16.1	96.6
1680-D03-0A-019	1	05-21-71	.5	1.5	276.0	508.7	515.2	4.0	5.4	23.7	92.9	89.8	7626.8	473.3	424.8	4.2	.7	8.7	3.3	10.6	20.9	95.6
1680-D03-0A-019	2	05-21-71	3.0	8.0	284.5	508.0	523.5	4.0	5.5	25.1	92.8	90.0	7622.5	473.3	425.8	4.2	.7	8.6	3.3	11.3	19.4	95.9
1680-D03-0A-019	3	05-21-71	9.2	11.5	289.1	510.9	528.0	3.9	5.0	19.1	94.2	91.0	7745.8	473.3	430.5	4.1	.7	8.7	3.4	7.2	18.8	96.0
1680-D03-0A-020	1	05-21-71	.6	1.0	279.2	503.2	515.1	4.0	5.5	24.5	92.9	89.4	7623.7	473.3	423.3	4.3	.8	8.7	3.3	11.3	21.6	95.4
1680-D03-0A-020	2	05-21-71	4.0	6.0	285.4	506.5	522.5	4.0	5.5	25.0	92.8	89.9	7618.3	473.3	425.4	4.2	.7	8.7	3.3	11.4	19.6	95.9
1680-D03-0A-020	3	05-21-71	10.0	14.0	289.5	511.0	528.8	4.0	5.0	19.1	94.1	90.5	7732.8	473.3	428.4	4.1	.7	8.7	3.4	7.3	20.8	95.6
1680-D03-0A-020	4	05-21-71	17.0	22.0	279.5	516.4	532.4	4.0	6.0	30.5	91.5	87.4	7507.5	473.3	413.7	4.3	.7	8.6	3.3	15.6	27.2	94.2
1680-D03-0A-020	5	05-21-71	30.0	50.0	268.4	516.9	531.7	5.0	7.3	29.6	90.3	87.3	7182.0	470.4	410.5	6.1	1.7	8.8	3.2	23.0	16.9	96.4
1680-D03-0A-021	1	5-21-71	5.0	50.0	93.9	501.3	519.0	4.5	5.9	21.4	92.8	88.5	7514.5	472.4	418.1	5.1	1.2	11.2	3.3	12.5	21.0	95.6
1680-D03-0A-021	2	05-21-71	55.0	105.0	93.1	493.5	519.5	4.4	6.2	26.6	91.6	87.1	7429.3	472.7	411.9	5.0	1.1	11.0	3.2	15.8	24.7	94.8
1680-D03-0A-022	1	06-15-71	8.0	13.0	293.1	340.9	199.6	3.9	5.6	28.2	90.8	91.3	7338.1	463.2	423.0	3.3	.6	8.1	3.3	12.9	12.0	97.4
1680-D03-0A-023	1	06-15-71	9.0	14.0	287.4	321.1	199.5	4.0	5.8	28.0	89.2	88.5	7187.3	463.5	410.3	3.6	.7	8.1	3.2	13.9	23.6	94.9
1680-D03-0A-023	2	06-15-71	19.0	23.0	256.5	319.4	201.9	5.2	7.7	29.5	86.1	84.2	6719.8	461.8	388.8	5.8	1.9	8.3	3.1	28.1	25.9	94.4
1680-D03-0A-023	3	06-15-71	30.0	34.0	284.3	324.5	234.6	4.1	5.5	24.1	88.8	89.7	7154.5	463.5	415.5	3.6	.7	8.1	3.3	11.1	21.2	95.4
1680-D03-0A-023	4	06-15-71	36.0	50.0	282.7	331.5	232.0	4.1	5.3	20.0	89.0	89.9	7158.7	463.6	416.6	3.8	.7	8.2	3.3	9.0	22.0	95.3
1680-D03-0A-023	5	06-15-71	54.0	58.0	285.7	339.2	227.6	4.1	5.5	23.9	89.7	89.2	7230.2	463.6	413.6	3.7	.7	8.2	3.3	11.2	22.9	95.1
1680-D03-0A-024	1	06-18-71	5.0	16.0	479.5	530.8	541.7	4.0	5.7	29.0	92.2	91.2	7596.4	473.5	432.0	2.3	.5	7.7	3.4	12.6	14.9	96.8
1680-D03-0A-024	2	06-18-71	19.0	23.0	486.1	528.9	543.0	3.9	5.3	24.3	93.4	92.5	7694.3	473.5	438.1	2.3	.5	7.8	3.4	9.3	12.0	97.5
1680-D03-0A-024	3	06-18-71	26.0	34.0	480.3	528.0	541.7	4.0	5.7	29.0	92.4	91.8	7607.8	473.5	434.9	2.3	.5	7.7	3.4	12.7	11.9	97.5
1680-D04-0A-012	1	07-16-71	5.0	25.0	298.9	530.5	549.8	3.8	5.2	24.2	93.2	92.7	7681.1	473.3	438.8	3.8	.6	8.4	3.4	9.4	8.8	98.1
1680-D04-0A-012	2	07-16-71	30.0	45.0	302.5	521.3	547.4	3.8	4.8	18.9	94.0	93.9	7748.7	473.3	444.5	3.8	.6	8.4	3.5	6.2	6.3	98.7
1680-D04-0A-012	3	07-16-71	49.0	59.0	302.6	517.5	544.0	3.8	4.7	16.9	94.0	94.2	7752.5	473.3	445.9	3.8	.6	8.4	3.5	5.3	5.8	98.8
1680-D04-0A-012	4	07-16-71	63.0	65.0	292.2	516.1	542.5	3.9	5.7	29.8	91.3	91.9	7513.1	473.3	435.1	4.0	.6	8.3	3.4	13.8	8.0	98.3
1680-D04-0A-012	5	07-16-71	68.0	73.0	281.7	515.9	542.2	4.8	7.1	29.0	90.1	89.7	7209.9	471.1	422.7	5.8	1.5	8.7	3.3	21.1	8.0	98.3
1680-D04-0A-012	6	07-16-71	78.0	94.0	284.7	515.1	542.0	4.9	6.7	24.1	91.5	91.0	7306.4	470.9	428.4	5.9	1.6	8.8	3.4	17.2	5.6	98.8
1680-D04-0A-014	1	07-21-71	2.0	6.0	448.8	547.8	546.2	3.4	4.6	24.1	95.6	95.2	7959.9	472.6	449.9	1.7	.3	7.3	3.5	5.4	4.5	99.1
1680-D04-0A-014	2	07-21-71	7.5	11.5	468.7	546.1	544.8	4.9	6.8	25.2	92.9	92.1	7423.0	470.9	433.6	3.5	1.4	8.2	3.4	18.2	2.6	99.4
1680-D04-0A-018	1	08-03-71	5.0	12.0	285.7	454.1	184.4	3.0	3.8	18.9	97.2	95.0	7931.3	458.1	435.3	1.3	.3	7.3	3.4	3.9	6.6	98.6
1680-D04-0A-018	2	08-03-71	16.0	24.0	285.8	433.3	191.1	3.0	3.5	13.9	97.5	94.9	7957.8	457.3	434.0	1.1	.3	7.2	3.4	2.8	8.3	98.2
1680-D04-0A-018	3	08-03-71	25.5	27.5	281.0	424.1	208.1	3.1	3.9	19.4	97.2	94.3	7935.9	458.4	432.4	1.3	.3	7.3	3.4	4.0	9.6	97.9
1680-D04-0A-018	4	08-03-71	30.0	32.5	276.1	419.9	213.3	3.1	4.3	24.7	96.7	94.3	7889.1	459.1	432.9	1.4	.4	7.4	3.4	5.6	8.0	98.3
1680-D04-0A-018	5	08-03-71	35.0	45.0	276.7	412.4	198.8	4.1	5.7	24.6	94.5	92.2	7608.9	463.6	427.6	3.8	.8	9.1	3.4	12.1	7.0	98.5
1680-D04-0A-018	6	08-03-71	47.0	58.0	266.3	407.0	188.3	4.2	5.5	19.9	95.6	93.2	7674.0	463.7	432.1	4.0	.9	9.1	3.4	9.7	4.6	99.0
1680-D04-0A-018	7	08-03-71	60.0	70.0	267.5	404.3	190.8	4.2	5.3	17.7	96.1	93.7	7720.3	463.7	434.4	3.9	.9	9.1	3.4	8.1	3.9	99.2
1680-D04-0A-018	8	08-03-71	72.0	74.0	266.2	403.9	192.1	4.2	5.5	20.3	95.7	93.3	7687.8	463.7	432.8	3.9	.8	9.1	3.4	9.8	3.8	99.2
1680-D04-0A-018	9	08-03-71	76.0	79.0	268.1	404.1	192.5	4.0	5.5	24.7	95.2	93.1	7672.2	463.5	431.3	3.6	.7	8.9	3.4	11.4	4.3	99.1
1680-D04-0A-018	0	08-03-71	81.0	91.0	262.3	405.5	193.8	4.9	6.6	22.7	94.2	91.4	7418.9	462.7	422.8	5.2	1.6	9.1	3.3	16.9	3.8	99.2
1680-D04-0A-018	1	08-03-71	94.0	101.0	268.0	408.0	191.9	4.8	6.1	18.7	95.4	92.8	7541.3	463.1	429.9	4.9	1.4	9.2	3.4	12.4	1.8	99.6

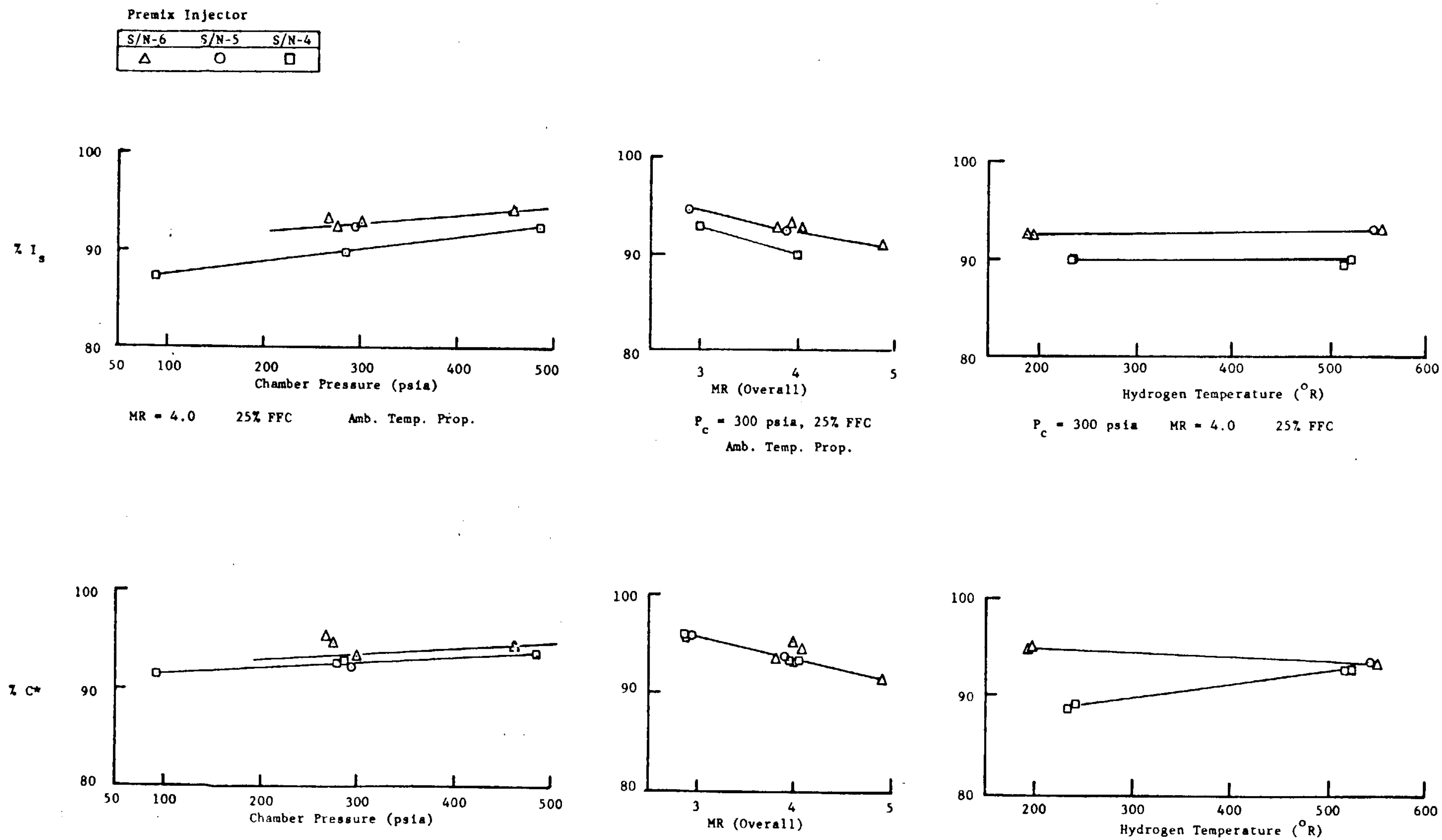


Fuel Temp.	Amb.	200°R		Amb.	200°R		Amb.	200°R
Face Temp,* °F	387-558	--		979	--		525-815	188-270
ΔP Fuel,* psia	57	23		70	--		72	36
ΔP Oxidizer,psia	62	36		49	--		77	40

* MR = 4.0 @ 300 psia - 20% film cooling

Premix Injector Element Configurations

Figure 1



Film Cooled Chamber Performance vs Pressure, Mixture Ratio and Propellant Temperatures

Figure 3

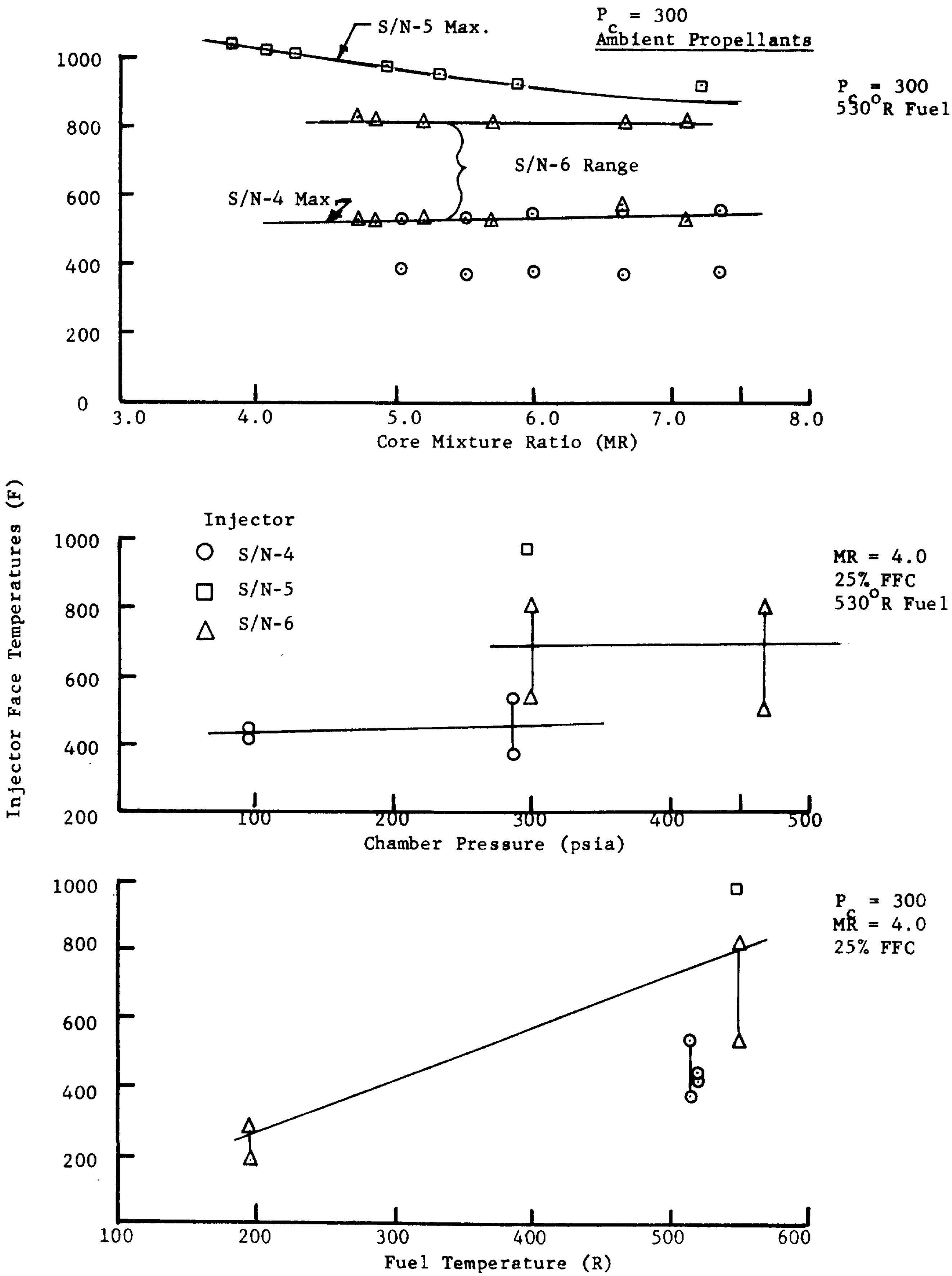
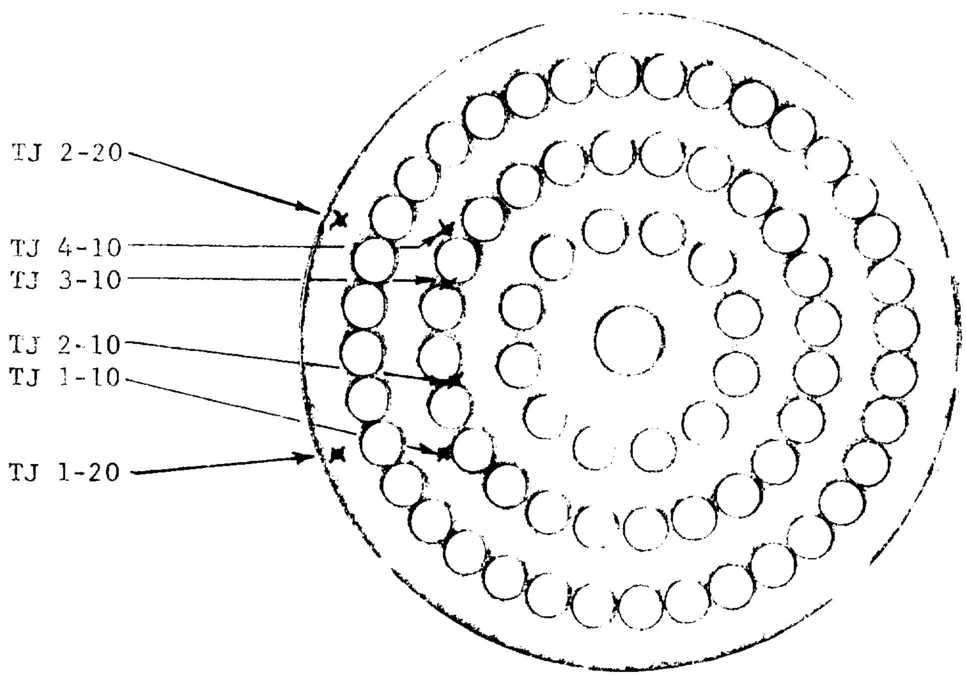


Figure 4. Injector Face Temperatures

Injector Face Thermocouple Location
(S/N-6 and S/N-7)

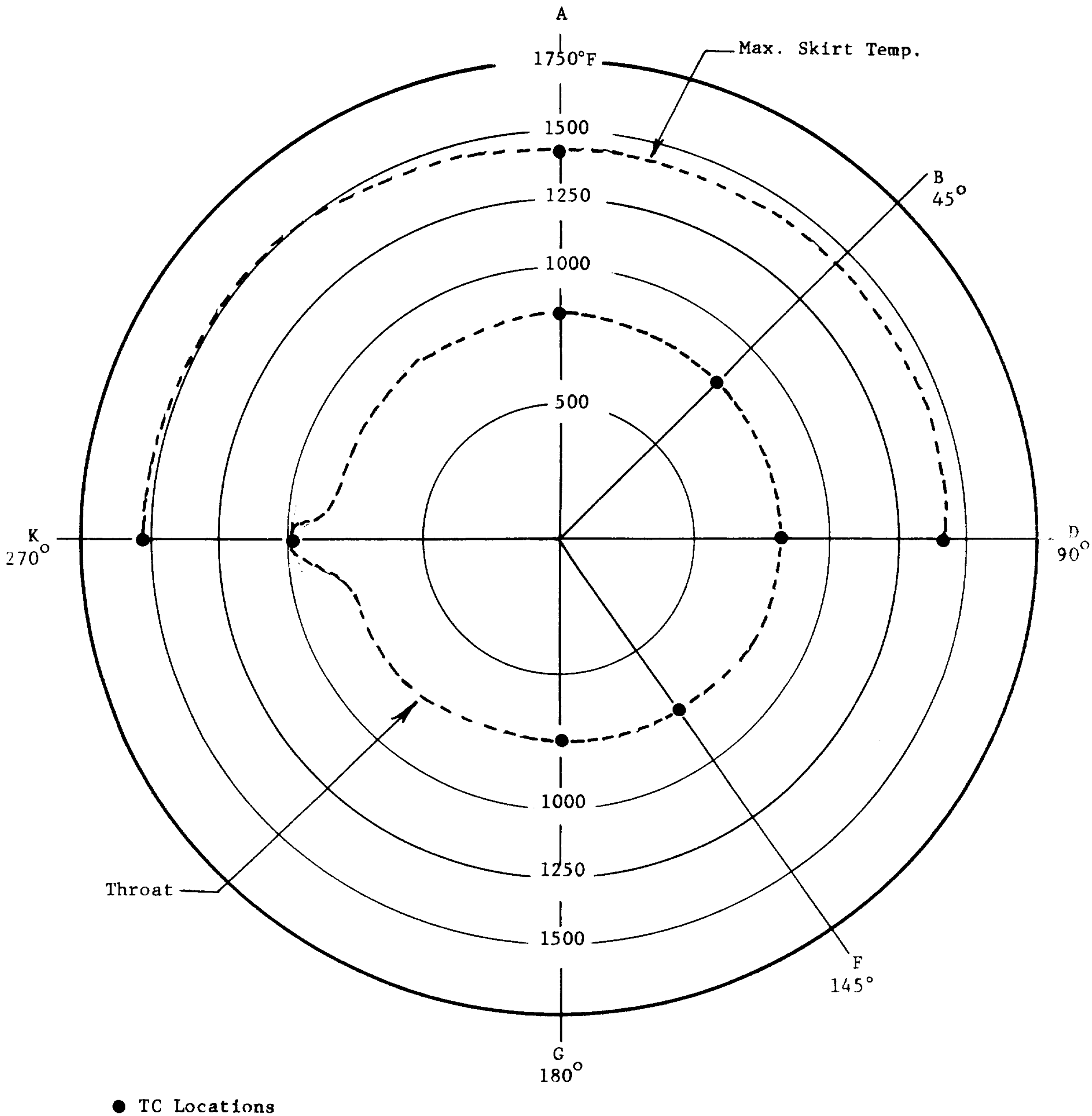


S/N-6 Face Temperatures**, ^{o}F

MR	3	4	5	4	5
H_2 Temp ^{o}R	200	200	200	530	530
TJ 1-20	346	259	193	756	805
TJ 2-20	178	187	190	566	381
TJ 1-10	*	*	*	546	555
TJ 2 10	220	210	227	529	367
TJ 3 10	250	265	288	555	567
TJ 4 10	375	260	364	813	808

*TC Junction Open
**300 psia MR = 4.0 25% FFC - S/N-1 FC Chamber

Figure 5. Injector Face Thermocouple Locations
(S/N-6 and S/N-7)



Peripheral Temperature Distribution
Test No. 1680-D04-0A-012
P_c = 299   MR = 3.8   25% FFC

Figure 6